F

Orange Beach High-Rise Study

Post-Ivan High-Rise Damage Survey

High-rise buildings along the Orange Beach, Alabama, Gulf of Mexico shoreline (seaward of Perdido Beach Boulevard.) were inspected by FEMA contractors between November 3 and 18, 2004. The purpose of the inspections was to determine the numbers and elevations of lowest floor living units that were damaged or destroyed by flood effects during Hurricane Ivan. Given the large number of damaged multi-family buildings that would not be classified as substantially damaged, an attempt was made to identify those lowest floor living units that could be repaired or reconstructed in-place, and which would have been classified as substantially damaged had they been individual buildings.

Building data were collected using a data sheet (see Figure F-1) and information from the data sheets was tabulated. A total of 43 buildings were inspected (see Figure F-2). Two buildings collapsed and would be classified as substantially damaged, and were removed from the study sample. Characteristics of the remaining 41 buildings are summarized in Table F-1.

Table F-1. Summary of Orange Beach, Alabama, High-Rise Buildings Inspected

Buildings Inspected (43)	
Number of Buildings Inspected	43
Total Number of Living Units	3,567
Collapsed Buildings (2)	
Number of Buildings Collapsed	2
Number of Living Units, Collapsed Buildings	70
Standing Buildings (41)	
Number of Buildings	41
Number of Living Units	3,497
Average Number of Living Units (range = 18 to 247)	85
Average Number of Stories (range = 5 to 15)	11
Number of Buildings with Living Units on Lowest Floor	39
Number of Living Units, Lowest Floor	233
Number of Buildings with Lobby/Common Area on Lowest Floor	28

Figure F-3 shows the lowest floor elevations of the 41 buildings used for the analysis. Figure F-4 shows the numbers of lowest floor living units versus lowest floor elevation.

FEMA

PROJECT: FEMA 1549DR-Alabama, Hurricane Ivan - Building Failure Analysis for Coastal Construction

COMM. NO. 01003C **PREL.** 12/17/2004 **FINAL** **SHEET** Bald-6

Unit ID: 1003

Building Name:

Address: Perdido Beach Boulevard

Closest Municipality: Orange Beach **County:** Baldwin **State:** AL

Survey Project: Hurricane Ivan Condominium Report **Survey Date:** 11/18/2004

Survey Company: **Survey Crew:**

Survey Latitude: 30.2616 **Northing:** 94150 **Vertical Datum:** NGVD1929

Survey Longitude: 87.6157 **Easting:** 1931466 **Horizontal Datum:** NAD1983

Use on Lowest Floor (check all that apply)

Parking ☐ **Lobby/common** ☑ **Living Units** ☑

No. of Living Units on the Lowest Floor: 4 **Elevation of Top of Lowest Floor (ft NGVD):** 18.66

Elevation of Bottom of Lowest Horizontal member Supporting the Lowest Floor (ft NGVD): 13.74

HVAC: Units on roof damaged

	Lowest Slab Damage*				Wall/Interior Damage**		
	No Damage	Damaged	Destroyed	Vertical Erosion Height below slab (ft)	No Damage	Damaged	Destroyed
Living Units***			4	8			4
Common Area			x	6			x
Parking Area							

* Slab damage: no = intact, no major cracking; damaged = major cracking, partial settlement; destroyed = total or major collapse

** Wall/Interior damage: no = walls and interior intact; damaged = portions of wall pushed in, windows/doors broken; destroyed = entire wall collapsed interior gutted

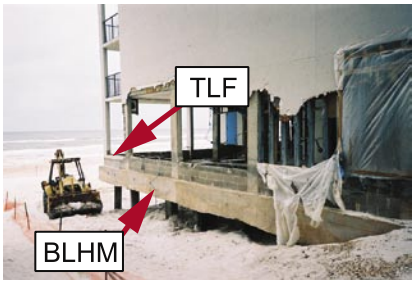
*** Indicate number of living units with no slab damage, damaged slabs, destroyed slabs. Indicate number of living units with no wall/interior damage, damaged walls/interior, destroyed walls/interior

Comments:

Some walls on 2nd floor damaged.

BLHM = **B**ottom of **L**owest **H**orizontal **M**ember **TLF** = **T**op of **L**owest **F**loor **BL** = **B**asement **L**evel

Street Side



Erosion

Figure F-1. Sample data sheet for Orange Beach high-rise study

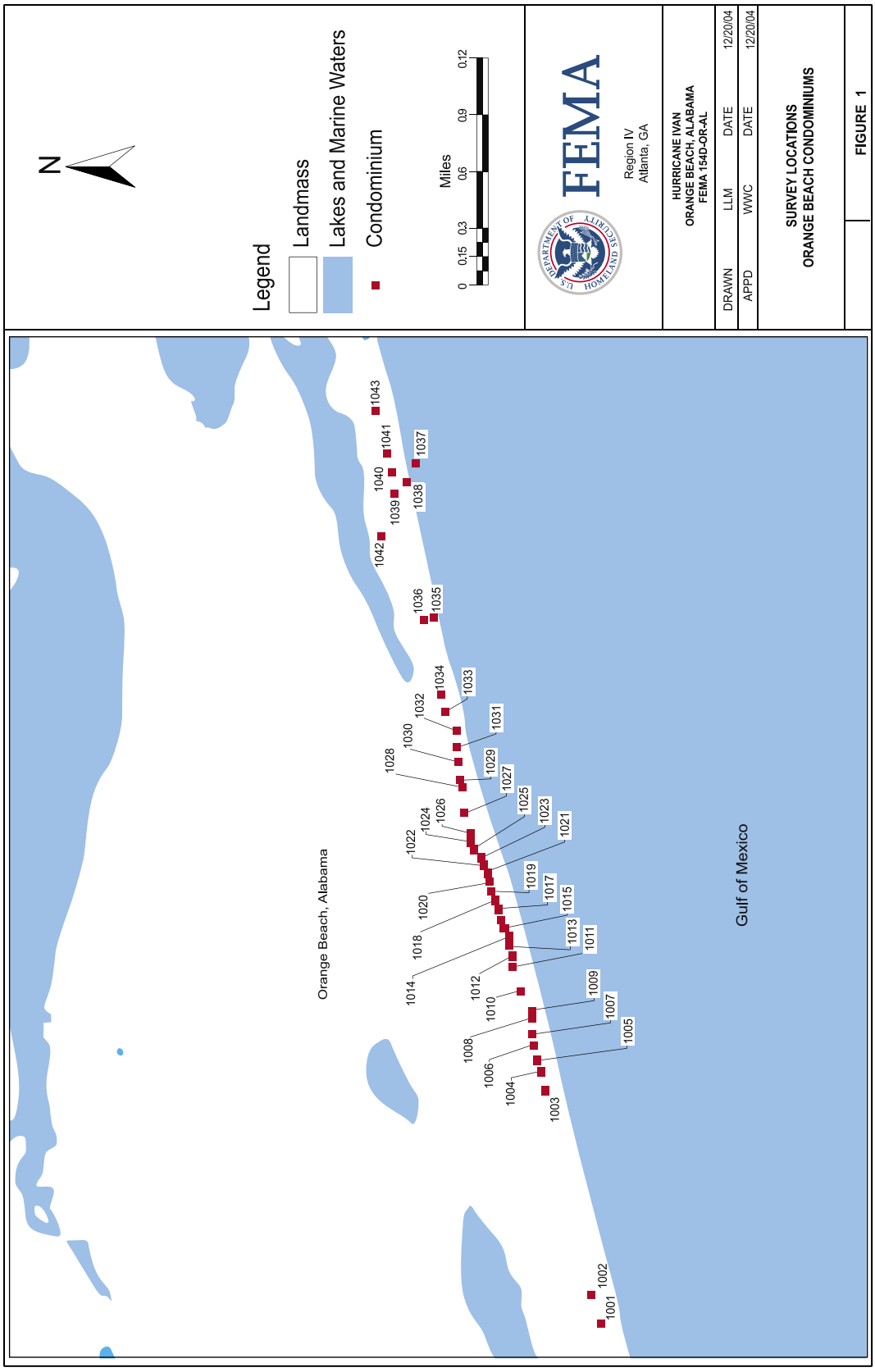


Figure F-2. Locations of 43 high-rise buildings inspected in Orange Beach, Alabama (numbers are code numbers assigned during inspections)

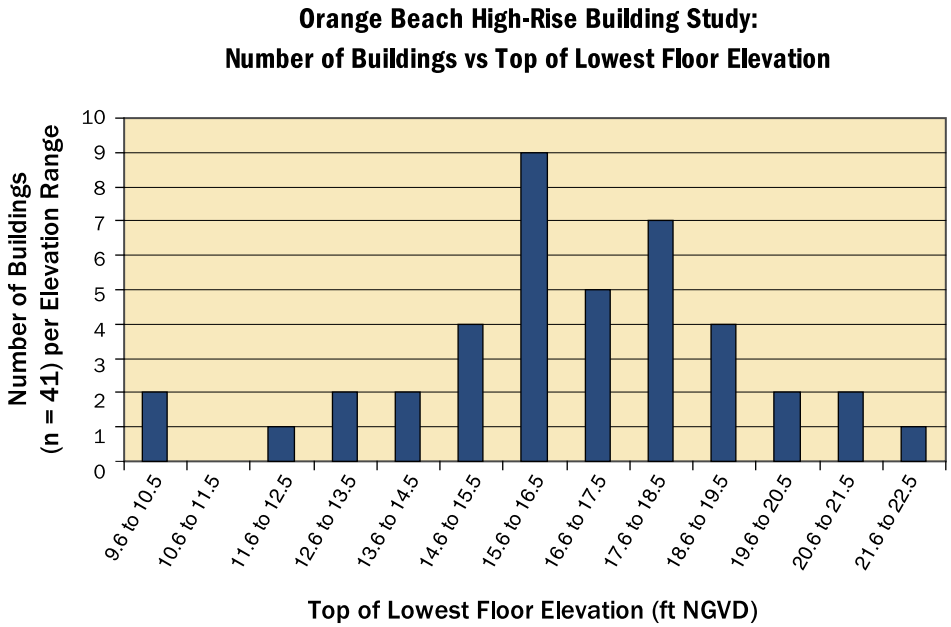


Figure F-3.
Top of lowest floor elevations for Orange Beach high-rise buildings

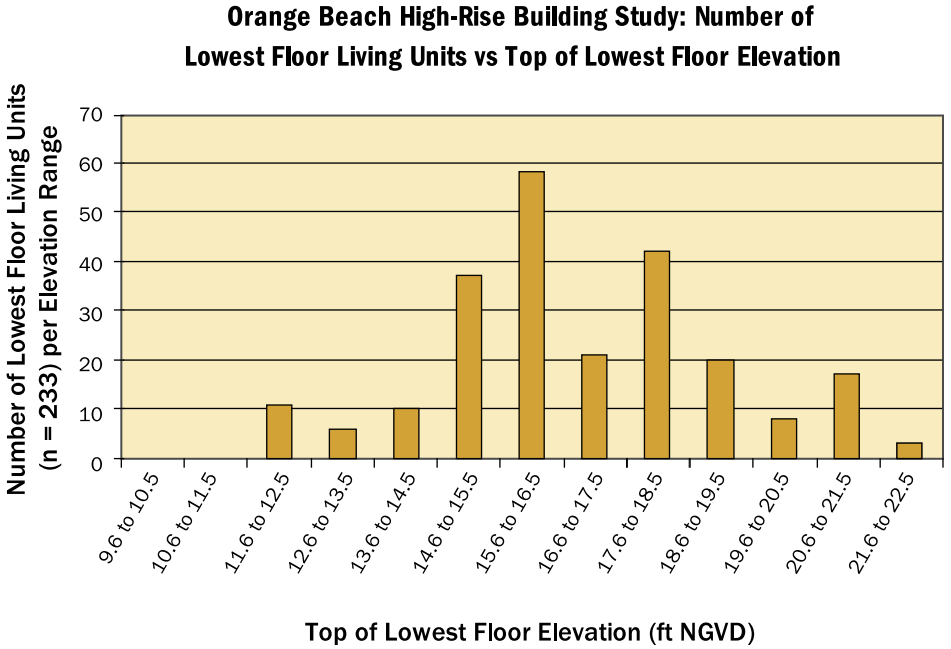


Figure F-4.
Lowest floor living unit elevations

The lowest top-of-lowest-floor elevation was 10 feet the National Geodetic Vertical Datum (NGVD), but the lowest living units were at 12.5 feet NGVD; the highest top of a lowest floor was 21.9 feet NGVD. Approximately two-thirds of the tops of lowest floors and lowest floor living units were between 14.6 feet NGVD and 18.5 feet NGVD.

Inspections showed the bottom of the lowest horizontal supporting member (BLHM) of the lowest floor (excluding pile caps) varied from

approximately 1 feet to 7 feet below the top of the lowest floor (average difference approximately 2.5 feet). Thus, for most of the buildings and lowest floor living units, the bottom of the lowest horizontal supporting members (excluding pile caps) lie between approximately 10 feet NGVD and 18 feet NGVD (average BLHM elevation approximately 14.5 feet NGVD).

Although the dates of construction for the inspected buildings are not known, these floor elevations are consistent with the 1983, 1985 and 2002 FIRMs for the region (see Section 2.2.1), which mapped the area seaward of Perdido Beach Boulevard as zones C, B, AE (elevation 9 to 13 feet NGVD) and VE (elevation 10 to 16 feet NGVD).

Building Damage States

Lowest floor damages were classified into nine "damage states" (see Table F-2) based on combinations lowest floor damage and damage to walls at the lowest floor level. The best case was no damage (lowest floor intact, walls intact). The worst case was complete destruction (lowest floor destroyed, walls destroyed).

Table F-2. Description of Damage States Used in the Orange Beach High-Rise Study

Component	Damage State	Description
Lowest Floor	Intact	intact, no major cracks
Lowest Floor	Damaged	major cracking and/or partial settlement
Lowest Floor	Destroyed	total or major collapse
Walls	Intact	walls and interior intact
Walls	Damaged	portions of walls pushed in, and/or doors/windows broken
Walls	Destroyed	entire wall collapsed and interior gutted

Table F-3 summarizes the frequency of observed damage states at the 41 buildings inspected. Table F-4 summarizes the frequency of observed damage states for the 233 lowest floor living units. A review of Tables F-3 and F-4 shows:

- 13 percent of the buildings and 12 percent of the lowest floor living units sustained no damage whatsoever (floor intact, walls intact). See Figure F-5.

- The most common lowest floor living unit damage state encountered was "floor intact, walls destroyed," occurring in 44 percent of the buildings and 43 percent of the lowest floor living units. See Figure F-6.
- 31 percent of the buildings and 25 percent of the lowest floor living units sustained complete lowest floor destruction (floor destroyed, walls destroyed). See Figure F-7.
- 183 (79 percent) of the lowest floor living units sustained wall destruction (across all floor damage states). These units would likely have been classified as substantially damaged had they been individual buildings instead of units of high-rise structures.

Table F-3. Orange Beach High-Rise Buildings (n = 41) Classified by Lowest Floor Living Unit Damage States

Wall Condition \ Floor Condition	Intact	Damaged	Destroyed	Sums	
Intact	6	0	0	6	6
Damaged	2	1	1	4	42
Destroyed	21	2	15	38	
Sums	29	3	16	*	
	29	19			*

* sums exceed 41 since some buildings experienced more than one floor-wall damage combination

Table F-4. Numbers of Lowest Floor Living Units Classified by Damage States (n = 233) for 41 Orange Beach High-Rise Buildings

Wall Condition	Floor Condition: Intact	Floor Condition: Damaged	Floor Condition: Destroyed	Sums	
Intact	28	0	0	28	28
Damaged	18	1	3	22	205
Destroyed	101	24	58	183	
Sums	147	25	58	233	
	147	86			233

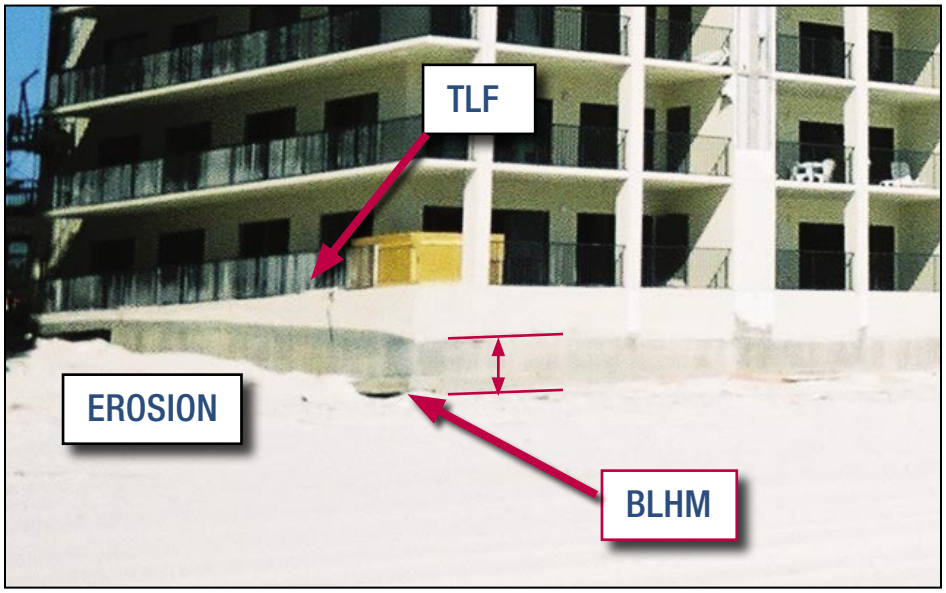


Figure F-5. Floor intact, wall intact damage state

Figure F-6.
Floor intact, wall destroyed damage state

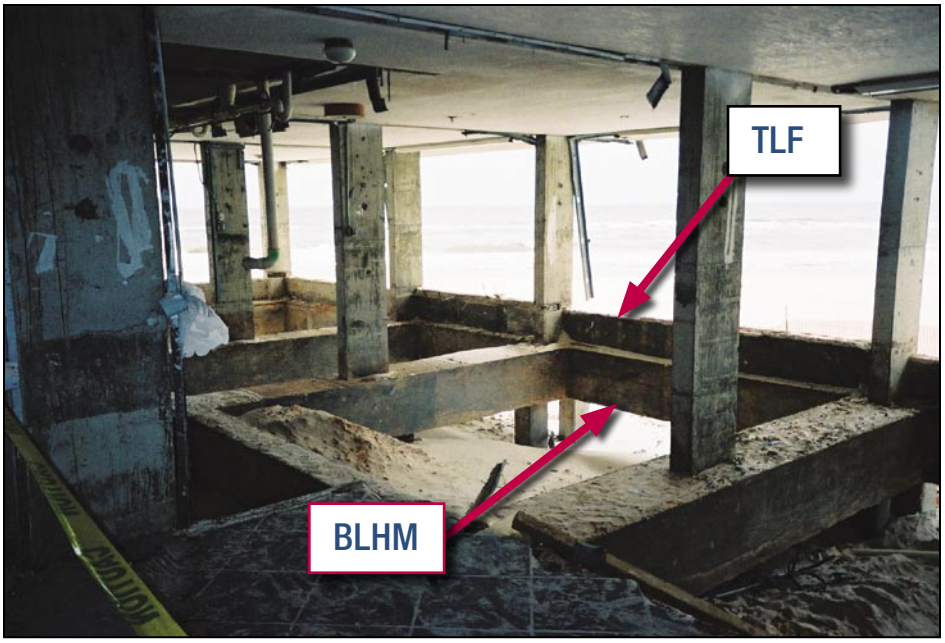


Figure F-7.
Floor destroyed, wall destroyed damage state

Building Damage versus Lowest Floor Elevation

Building damage states were compared against lowest floor elevations. Not surprisingly, buildings with the lowest floor elevations had more wall and floor destruction than buildings with higher floor elevations (see Table F-5, Figure F-8 and Figure F-9).

Note that even though the number of lowest floor living units above elevation 19.6 feet was less than 10 percent of the total number of lowest floor living units (see Figure F-4), these units accounted for 75 percent of the total number of undamaged lowest floor living units – units at higher floor elevations had a better survival rate.

Similarly, 69 percent of the totally destroyed lowest floor living units were below elevation 16.5 feet NGVD, even though only 52 percent of the total number of lowest floor living units were below this elevation – units at lower elevations had a greater likelihood of being destroyed.

Review of Hurricane Ivan water levels at Orange Beach (see Table 1-2 and Figure 1-10) show that water levels reached elevations of approximately 12 to 15 feet NGVD, which exceeded the BFEs there. The Ivan water levels may have included wave setup and some wave effects, but probably did not reflect the true wave crest elevation, which could have been several feet higher than the measured water levels. The fact that lowest floor living units survived intact only when the floor elevation exceeded 19 feet NGVD is consistent with this, and reinforces the importance of adding freeboard – designing and constructing buildings above the minimum elevations required by the NFIP.

Table F-5. Damage States versus Top of Lowest Floor Elevation*

Damage State	Number of Buildings (n)	Average Top of Lowest Floor Elevation (ft NGVD)
Floor Intact, Wall Intact	6	19
Floor Intact, Wall Destroyed	21	17.4
Floor Destroyed, Wall Destroyed	15	15.9

* damage states not included in table for small n

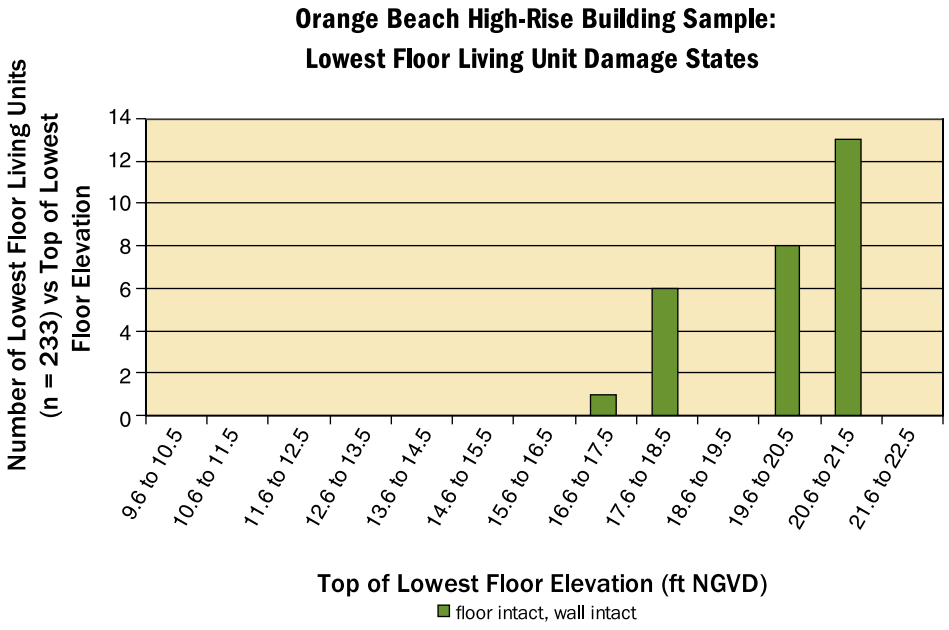


Figure F-8.
Floor intact, wall intact damage state versus top of lowest floor elevation

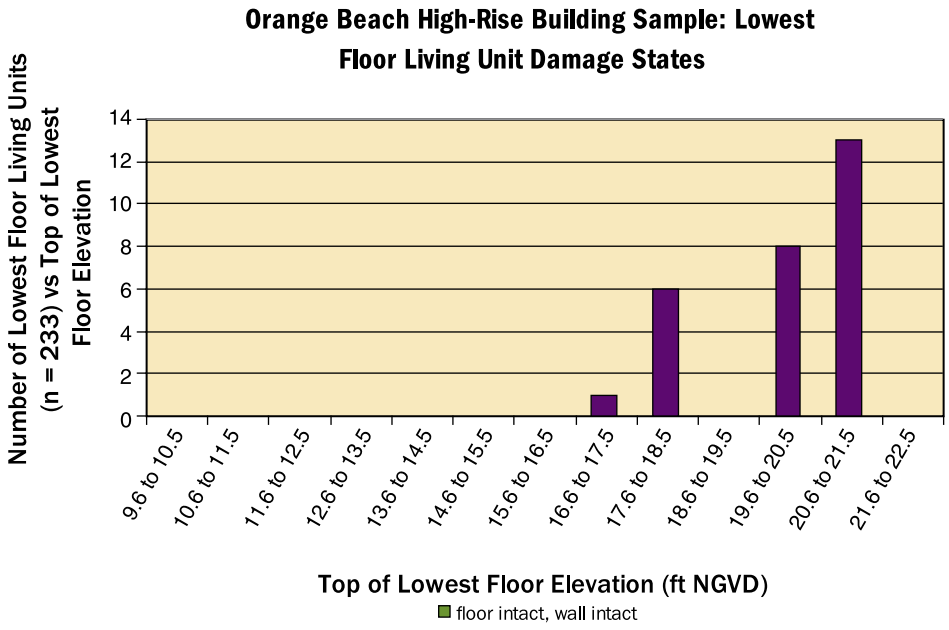


Figure F-9.
Floor destroyed, wall destroyed damage state versus top of lowest floor elevation

Building Damage versus Erosion Depth

Building damage states were also compared against erosion depth at the building foundations. Not surprisingly, buildings with the greatest erosion depths had more wall and floor destruction than buildings with lower erosion depths (see Table F-6). Low erosion depths were associated with buildings sited farther from the shoreline, and buildings near the east end of Orange Beach, where sand trapped against the East Pass jetty produced a wide beach seaward of the buildings.

Table F-6. Damage States versus Average Erosion Depth*

Damage State	Number of Buildings (n)	Average Erosion Depth (ft)
Floor Intact, Wall Intact	6	1.3
Floor Intact, Wall Destroyed	20	7
Floor Destroyed, Wall Destroyed	15	6

* damage states not included in table for small n

Summary of Findings

- While the exact construction requirements for each building (i.e., the effective flood hazard zones and BFEs at the time of construction) are not certain, all but two of the high-rise structures examined were constructed with pile foundations – which prevented total collapse of the structures.
- The buildings, as a whole, performed well structurally, although a high percentage of the lowest floor living units and common areas were damaged or destroyed by Ivan's flood effects and erosion. Lowest floor damage could have been prevented or reduced by adherence to current VE zone construction standards and use of freeboard to elevate the lowest floors several feet above the BFE.
- Elevating the lowest floor one story above the BFE and using the space below the BFE for parking would be the most appropriate means of reducing lowest floor living unit damage to new high-rise buildings in the area.